Alpine Entomology 3 2019, 121–136 | DOI 10.3897/alpento.3.33944

PENSOFT

Alpine Entomology

Review of the endemic New Zealand genus *Arctesthes* Meyrick (Lepidoptera, Geometridae, Larentiinae), with descriptions of two new range-restricted species

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http://zoobank.org/F242A4EA-12CF-4F73-90A5-4CBACF71FD10

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Received 19 February 2019
Accepted 14 April 2019
Published 29 May 2019

Academic editor:
Peter Huemer

Key Words

New Zealand
Southern Alps
Geometridae
Larentiinae
Xanthorhoini
new species
conservation

Abstract

The genus *Arctesthes* Meyrick (Geometridae: Larentiinae: Xanthorhoini), endemic to the South Island of New Zealand, is revised. Four species are recognised, including two new species, as follows: *Arctesthes catapyrrha* (Butler, 1877), *A. siris* (Hudson, 1908), *A. titanica* **sp. nov.** and *A. avatar* **sp. nov.** All except *A. catapyrrha* are restricted to subalpine and alpine localities. Adults and genitalia are fully described and illustrated for all species; larvae of *A. catapyrrha* are also briefly described and illustrated. Only *Arctesthes catapyrrha* is widespread; *A. siris* is restricted to a few mountain ranges of Central Otago; *A. titanica* is only known from two wetland localities in the Von Valley of the Otago Lakes district, and *A. avatar* is only known from a few wetlands in a restricted area of north-west Nelson. The two new species are considered of very high priority for conservation.

Introduction

New Zealand has a relatively diverse and almost entirely endemic fauna of Geometridae, with Larentiinae by far the best represented subfamily (e.g., Dugdale 1988). Within Larentiinae, Xanthorhoini contains a few endemic genera (e.g., *Notoreas* Meyrick, *Asaphodes* Meyrick) that have radiated extensively in the alpine areas of the South Island; there are also genera (e.g., *Aponotoreas* Craw) that are shared with Australia. The larentiine fauna remains largely unrevised, and much further work is needed at both genus and species level. Craw (1987) usefully summarised the history of the genus classification of New Zealand Xanthorhoini. We here revise the small, endemic xanthorhoine genus *Arctesthes*.

Butler (1877) described the attractive little diurnal *Arctesthes catapyrrha* (as *Fidonia* (?) *catapyrrha*), from specimens brought to England by J. Hector and J.D. Enys. It was made the type and only species of a new genus *Stratonice* by Meyrick (1884); he later replaced this preoccupied name with *Arctesthes* (Meyrick 1885a). He also (Meyrick 1885b) incorrectly synonymised *catapyrrha* with a superficially similar Australian species, *Coremia euclidiata* Guenée (now *Chrysolarentia euclidiata*: see, e.g., McQuillan and Edwards 1996), and this was followed by subsequent authors (Fereday 1898, Hudson 1898), until Longstaff (1912: 114) pointed out the error.

Ironically, the only species hitherto assigned to the genus *Arctesthes* in its original description is *A. chrysopeda*,

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described by Meyrick (1888) (under *Arcteuthes*, a misspelling). This species is not an *Arctesthes*; it was transferred to its current placement in *Notoreas* by Craw (1986). Hudson (1898) referred *catapyrrha* (as *euclidiata*) and *chrysopeda* to the European genus *Lythria* (actually a genus of Sterrhinae: Õunap et al. 2008), presumably on the advice of Meyrick, who adopted the same classification in his later revision of New Zealand Geometridae (Meyrick 1917). The new species *siris* from Central Otago was also described by Hudson (1908) in *Lythria*; the genus name *Arctesthes* had already fallen into disuse. It was resurrected by Craw (1986) in his review of the genus *Notoreas*.

The two *Arctesthes* species described here were discovered in 2004 and 2012, and are therefore the first new species of this genus found since the discovery of *A. siris* in 1906. They are closely related and very similar, but differ from the previously known species in their size and especially in some features of the genitalia, necessitating a broader definition of the genus. Since the two new *Arctesthes* species are readily identifiable and clearly distinct based on morphological characters, both external and genitalic, we have described them here without presenting data on DNA barcodes. However, molecular work is in progress and barcodes will be added to the Barcode of Life Data System (BOLD) when available.

All four *Arctesthes* species are confined to open grassland or wetland habitats of the South Island, and only *A. catapyrrha* has been found in lowland localities (below 600 m), though it is also common in the subalpine and alpine zones.

Materials and methods

Genitalia dissection followed standard techniques for Lepidoptera, as described by e.g. Robinson (1976) and Hoare (2000). Genitalia and abdominal pelts were mounted in Euparal on slides. Staining was with 1% Chlorazol Black E, except for abdominal pelts, which were stained first in Chlorazol Black, and then in a 3% solution of acid fuchsin in 70% ethanol. For some male specimens, the vesica was gently picked out from the phallobase using fine forceps; the diameter of the phallobase is too small to insert a syringe and allow inflation. Abdominal pelts were opened up along one side so that both tergites and sternites could be viewed in a single plane.

Terminology for wing markings follows Patrick et al. (2010). Two-letter abbreviations for regions of New Zealand follow Crosby et al. (1998), but are summarised here for readers unfamiliar with the system (order is roughly north to south through the South Island): NN Nelson; WD Westland; MB Marlborough; KA Kaikoura; MC Mid Canterbury; SC South Canterbury; MK Mackenzie; OL Otago Lakes; CO Central Otago; DN Dunedin; FD Fiordland; SL Southland.

The following acronyms are used for collections where specimens are held:

BLNZ: Brian Lyford private collection, Queenstown, New Zealand
BMNH: British Museum (Natural History), London, England
BPNZ: Brian Patrick private collection, Christchurch, New Zealand
MONZ: Museum of New Zealand Te Papa Tongarewa, Wellington, New Zealand
NZAC: New Zealand Arthropod Collection, Manaaki Whenua—Landcare Research, Auckland, New Zealand

Specimens currently in private collections are all destined for eventual deposition in New Zealand museums and research institutions.

Latitude and longitude for type localities was derived from the online gazetteer Topomap NZ (https://www.topomap.co.nz/) and not from GPS readings. We have designated a holotype but only a few paratypes of each new species, as paratypes have no name-bearing status in zoological nomenclature (cf. van Nieukerken et al. 2016: 4).

BHP keeps a record of all Lepidoptera seen by him in notebooks; numbers of records quoted for each species from these notes relate to the number of separate sightings (one sighting = presence on one date at one locality), i.e. a sighting may be of several or many specimens.

Taxonomy

Genus *Arctesthes* Meyrick, 1885

Arctesthes Meyrick, 1885. New Zealand Journal of Science 2: 589. Replacement name for *Stratonice* Meyrick, 1884 (Transactions and proceedings of the New Zealand Institute 16: 64; unavailable, preoccupied by *Stratonice* Malmgren, 1867 (Annelida: Polychaeta)). Type species: *Fidonia catapyrrha* Butler, 1877, by original monotypy.

Arcteuthes Meyrick, 1888. Transactions and proceedings of the New Zealand Institute 20: 47. Incorrect subsequent spelling.

Diagnosis. Based on the redescription by Craw (1986) and on comparison of specimens and genitalia slides in NZAC, *Arctesthes* is closely related to *Notoreas*. It can be distinguished from *Notoreas* by features of the male genitalia, as follows: in *Arctesthes* the juxta is a single tongue-like plate; in *Notoreas*, the base plate is emarginate and separated from a posterior sclerite (the ventral manica pad of Craw (1986)) by membrane; in *Arctesthes*, the labides are short to moderately long and robust (very short in *A. siris*); in *Notoreas*, they are usually long to very long and narrow; the costal sclerite of the valva in *Arctesthes* is small and smooth; in *Notoreas* it is very large and strongly scobinate. The larvae of *Notoreas* are restricted to Thymelaeaceae as host-plants; known larvae of *Arctesthes* are more or less polyphagous on herbaceous plants.

Redescription (updated from Craw (1986)). Small diurnal larentiines with cryptic forewings and black and orange hindwings. Head: male antennae bipectinate, with pectinations 3–5× width of flagellum; female antennae

simple. Male abdominal segments 7–8 reduced; S7 with short, eversible pouch-like coremata. Male genitalia: uncus moderately short to rather long, narrow, digitate, curved; valva more or less oblong, with costa sclerotised for ca ½ valva length and more or less projecting beyond outline; sacculus ending in small weakly scobinate cushion-like (*catapyrrha*, *siris*) or large, curved, spinulose projection (*titanica*, *avatar*); juxta tongue-like; dorsal manica pad strongly scobinate / coarsely spinulose; phallobase tapering; vesica with 2–3 small spine-like cornuti only (*catapyrrha*), with 3 spine-like cornuti and a comb-like group (*siris*) or with 2 comb-like groups of cornuti (*titanica*, *avatar*). Female genitalia : ovipositor lobes (papillae anales) forming compact 'pad', strongly setose throughout; apophyses posteriores long and narrow; apophyses anteriores much shorter and more robust; S8 sclerite narrow, strap-like; ostium very narrow (*catapyrrha*, *siris*) to very broad (*titanica*, *avatar*); ductus bursae variable in sclerotisation and rugosity; ductus seminalis arising dorsally at ductus / corpus bursae junction; corpus bursae weakly membranous, more or less round, without signa.

Distribution. Endemic to the South Island of New Zealand.

Biology. Adults diurnal. Known larvae (*catapyrrha*, *siris*) more or less polyphagous on low herbaceous plants in native and / or modified swards.

Remarks. Craw (1986: 132) included the following characters in his redescription of *Arctesthes*: 'sacculus reduced, no free arm; apex a rounded, low mound...vesica with three cornuti...ostium a narrow circular opening... ductus bursae much longer than wide'. These have been revised in the description above following the discovery of *A. titanica* and *A. avatar*. Males of both new species have a large free arm of the sacculus, and a pair of comb-like groups of cornuti in the vesica; females of both have a very broad ostium and a ductus bursae that is wider than long. Craw (1986) also overlooked the presence in *A. siris* of a set of close-set comb-like cornuti in the vesica; only *A. catapyrrha* has the cornuti reduced to 2 or 3 in number as per his description. In spite of their differences from the previously described species, *A. titanica* and *A. avatar* are referred to *Arctesthes* based on the other morphological characters mentioned in the Diagnosis above; as stated elsewhere, further studies on the phylogeny and genus classification of New Zealand Xanthorhoini are needed.

Arctesthes catapyrrha (Butler, 1877)

Figs 1–6, 14, 18, 20–23, 30, 34 (map)

Fidonia? catapyrrha Butler, 1877. Proceedings of the Zoological Society of London for 1877: 392, pl. 43 fig. 2.

Arctesthes catapyrrha kaikourensis Prout, 1939. In Seitz, A., The Macrolepidoptera of the World (Stuttgart) 12: 247. Described as subspecies; synonymised (by implication) by Dugdale (1988: 171, as 'ab. *kaikourensis*'); synonymy upheld here.

Type material. *Fidonia catapyrrha*: Lectotype: male (here designated), 'Type [red-ringed circular label] / N. Zeal. 77.34 / Fidonia catapyrrha Butler Type' (BMNH) (not examined, but photograph seen).

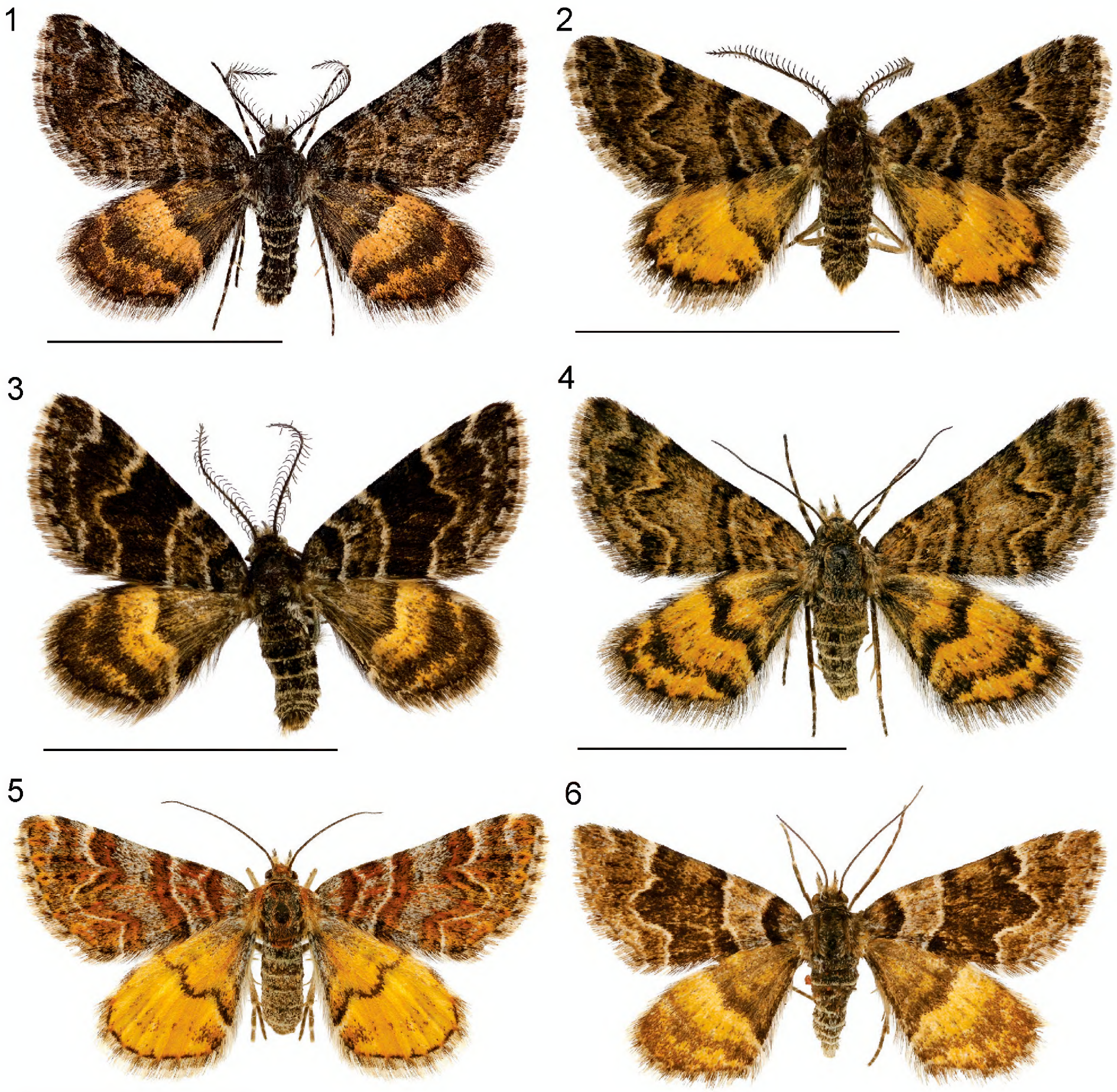
Note. *Fidonia catapyrrha* was described from an unspecified number of specimens, but since Butler (1877) stated that it was in both collections that he had received (from Enys and Hector), he clearly had more than one specimen. There is no mention of type material in the original description, so the type series must be regarded as syntypic (ICZN Article 73.1) and neither the labelling of a specimen by Butler as 'Type' (Dugdale 1988: 171) nor the mention of a holotype by Dugdale constitutes a valid lectotype designation (Article 74.5). The specimen hitherto regarded as holotype is here designated lectotype to prevent further confusion. Hector's collection was probably largely from Otago and Enys' from mid-Canterbury: Dugdale (1988: 171) suspected the lectotype to be from Canterbury based on the strong red flush on the hindwing underside, but this character is not restricted to Canterbury specimens and cannot be relied on as an indication of the type locality.

Arcesthes catapyrrha kaikourensis: Lectotype: male (designated by Dugdale (1988: 171)), 'Mt Tapuae-nuku (slopes of) 1.3.16 / 219z' (MONZ) (not examined but photograph seen).

Note. Prout (1939) clearly described *kaikourensis* as a subspecies rather than an aberration of *catapyrrha*, so the name is available under the Code; Dugdale (1988: 171) incorrectly listed the name as an aberration. The description of *A. c. kaikourensis* runs as follows: 'According to Hudson (1928): "a local variety occurs in the Kaikoura Mountains, having the upperside of the hindwing bright orange."' Based on this, and the lack of specimens under this name in the BMNH (J.S. Dugdale, notebooks), it is very likely that Prout took the remarkable action of describing the subspecies without seeing any material. This does not affect the availability of the name (ICZN Article 13.1). Specimens with bright orange hindwings occur perhaps throughout the range of *A. catapyrrha*, and there appears to us no evidence to support the separation of any populations as subspecies. Therefore the synonymy implied by Dugdale (1988) in indenting this name under *catapyrrha* is upheld here.

Diagnosis. Differences from *A. siris* and *A. titanica* are detailed under those species, below.

Redescription. *Adult male* (Figs 1–3, 14, 18): Wingspan 14–19 mm. Antennal pectinations long, up to ca 4–5× flagellum width. Labial palpi with numerous long erect black hairlike scales laterally and ventrally, mixed with long white hairlike scales ventrally. Head and thorax grey to blackish, with variable admixture of white scales, sometimes with suffusion or overlay of bright orange-brown scaling of varying extent; strip of pure white scales along antero-ventral margin of eye. Forewing ground colour (areas between transverse markings) grey to blackish depending on variable admixture of whitish scales; proximal line white to greyish, with gentle convex curve (away from wing base); antemedian line white to greyish, with gentle convex curve; discal dot black, more



Figures 1–6. *Arctesthes catapyrrha*, uppersides. **1)** Male, Yaldhurst MC; **2)** Male, Harris Mts OL **3)** Male, [locality unknown]; **4)** Female, Dunstan Range CO; **5)** Female, Ben Lomond OL; **6)** Female, Ben Lomond OL. Scale bars: 10 mm.

or less equidistant between antemedian and postmedian lines or closer to antemedian; central fascia usually pallid in central band around discal dot, dark lines or bands either side of this band parallel with antemedian and postmedian lines; postmedian line greyish to white, strongly sinuous, with large V- to U-shaped evagination centrally, section between evagination and costa straight to weakly convex; veins often more or less distinctly lined blackish beyond discal cell; distal line whitish, often indistinct; fringe basally more or less distinctly chequered, distally whitish to grey. Forewing sometimes with suffusion of bright orange-brown scaling, especially along veins and in terminal area. Hindwing ground colour bright orange; basal blotch more or less suffused blackish; antemedian line distinct, weakly W-shaped, blackish; postmedian line very variably developed, sometimes almost obsolete, sometimes more or less continuous with terminal line, leaving only narrow orange area between, blackish, weakly V-shaped; terminal line a blackish suffusion, often obsolete; series of black dashes along termen distinct in specimens with terminal line obsolete; fringe basally blackish, distally greyish to white, sometimes with weakly chequered appearance. Forewing underside (Fig. 14) pale to bright orange; antemedian line indistinct or absent; discal dot distinct, black; postmedian line usually distinct, black, sometimes double centrally, with strong median evagination; white spot on costa between postmedian line and subterminal fascia; subterminal fascia more or less developed as blackish suffusion bordering subterminal line towards costa, sometimes continued as narrower line

to tornus; subterminal line white, usually only distinct towards costa; terminal fascia blackish, often suffused bright reddish brown or rose-brown towards apex, sometimes obsolete (i.e. termen orange as ground-colour). Hindwing underside pale orange (this colour usually confined to a wedge-shaped streak in wing centre); a more or less well-defined strip along costa and around termen bright rose-brown, this colour sometimes extending as suffusion through centre of wing to base; broad white streaks subcostally and along anal margin to 2/3 length of wing; subbasal, antemedian and postmedian lines usually very distinct and rather broad, blackish, sometimes postmedian indistinct or obsolete; antemedian line sometimes preceded by distinct spot above middle; postmedian line with variably defined narrow white distal margin. Abdomen blackish, sprinkled white and with distal margin of each segment white; anal tuft mixed blackish and white.

Male abdomen and genitalia (Figs 21–23): S3-6 moderately elongate (rectangular), either uniformly well sclerotised or rather weakly sclerotised except along caudal margin; T2-6 either evenly sclerotised, or sclerotisation strongest in 2 lateral patches caudally on each segment. Uncus digitate, moderately robust, very blunt apically; labides robust, straight to gently curved, with weakly to strongly hooked apices; dorsal scobinate portion of manica with blunt teeth of various sizes; juxta tongue-shaped to arrowhead-shaped; valva very short, with smoothly rounded apex; basal costal sclerite with straight or concave costal edge, ending in blunt process more or less strongly projecting beyond valval costa; sacculus process a short rounded lobe, not reaching valval costa, finely and evenly scobinate; saccus short to long, blunt, Y-shaped, variably recurved under genital capsule. Phallus (Fig. 23) with tongue-like apical process; vesica with 2 or 3 small, rather weakly to moderately melanised spine-like cornuti.

Adult female (Figs 4–6): Wingspan 14–20 mm. Similar to male, but antennae without pectinations; labial palpi without lateral hairlike scales and with ventral scaling much shorter than in male, usually white without or with few black scales; forewing and hindwing both tending to be slightly narrower than in male; forewing markings tending to be better defined with cross-lines more distinct and central fascia often broader; hindwing upperside with postmedian line usually less distinct than in male.

Female genitalia (Fig. 30): Total length ca 2.4–2.8 mm. Ovipositor lobes subtriangular, apically blunt. S8 with strongly sclerotised, strongly concave, round to lobe-shaped lamella postvaginalis. Ostium round, narrow; antrum a variably distinct flask- or cup-shaped sclerotised chamber; ductus bursae with strongly rugose posterior portion and smoothly sclerotised anterior portion. Corpus bursae membranous, round to oblong.

Distribution. (Fig. 34). Widespread in the central and southern South Island, becoming very local north of mid-Canterbury and not definitely known from the Nelson district. Hudson (1928) gives 'near Nelson', but no specimens from this area have been seen in collections and the record requires confirmation.

WD, MB, KA, MC, SC, MK, OL, CO, DN, FD, SL

Biology. This small geometrid is widespread in open low vegetation in the eastern and central South Island, but also near the West Coast in riverbed vegetation. It is found in coastal turfs (i.e., saltmarsh, dune slacks, and river-mouth habitats) as well as riverbeds, river terraces, saltpans, kettleholes, lake-edge turfs and short tussock grasslands of the interior valleys; it also occurs up to 1920 m on the drier eastern and central South Island mountains in cushionfield, snow banks, wetland and open, often depleted grasslands. It can be locally abundant over cushionfield, bare ground or low herbs and grasses, flying by day low to the ground. It often settles and is easily observed as it sunbathes on bare ground or low vegetation, or feeds on flowers (e.g. *Aciphylla aurea* (Apiaceae), *Gentiana* spp. (Gentianaceae)). The species is a survivor and can sometimes be found in quite modified short and open grasslands, some of which are kept short by local management needs, such as at the Saint Clair Golf Course in Dunedin or Waimate Airstrip.

The brightly coloured larvae (Fig. 20) (Patrick and Chisholm 1989) are polyphagous, having been found and reared from various native and exotic plant species including *Trifolium* (exotic clover, Fabaceae), the creeping *Nertera balfouriana*, *Nertera setulosa*, and *Coprosma atropurpurea* (all Rubiaceae), *Scleranthus, Stellaria* and *Colobanthus* (all Caryophyllaceae), *Polygonum plebeium* (Polygonaceae), *Oreomyrrhis rigida* (Apiaceae) and the cushionplant *Raoulia tenuicaulis* (Asteraceae). In captivity the larvae will readily feed on *Plantago* and *Epilobium* and as these plants are present at many of its known sites, they are possible natural hostplants. Interestingly larvae have been observed in captivity to be cannibalistic on fellow larvae that had died. The larvae are active by day, and grow to 16mm. No detailed description of the larva is available, but a drawing of the habitus was provided by Craw (1986: fig. 21) and a brief description is made here from photographs (see Fig. 20): the head is reddish brown with paler marbling; prothorax red-brown dorsally; the body pale grey to rosy pink, with an interrupted broad green dorsal line on the abdominal segments, bordered by oblique subdorsal stripes that are green anteriorly and black posteriorly; there is some white between the dorsal line and the subdorsal stripes; the stripes merge on the thorax into a broad blackish subdorsal line tinged green centrally; anal prolegs brown. Larvae move forward with a quick, repetitive, jerking action.

The adults first appear by mid-September at low altitude sites, and the last records are from early May. Most alpine and high alpine records are between December and March. There appear to be up to three generations per year at lowland and inland montane sites, but perhaps just one at the highest altitudes.

Remarks. This is a common and widespread species: BHP has made 214 records since 1971 (BHP notebooks, Christchurch). There is considerable variation in the form of the saccus in the male genitalia of *A. catapyrrha*. While most specimens have a long saccus that is more or less

aligned with the genital capsule (Fig. 22), a few have a much shorter saccus that is recurved beneath the capsule. Since this character does not seem to align consistently with any other morphological character or any area of distribution, and since one specimen from Mt Maungatua DN (genitalia slide NZAC Geo. 45) has a saccus of intermediate form, no taxonomic significance is accorded to the variation here.

Prout (1939) described ab. *fasciata* as a form of *Arctesthes catapyrrha*. Dugdale (1988: 171) mentions a female 'holotype' collected by Philpott at Ben Lomond OL designated by Prout in the BMNH. Since the original description makes it clear that the name *fasciata* refers to an aberration, it is infrasubspecific and therefore unavailable (ICZN Article 45.6.2). The provisions of the Code do not apply (Article 1.3.4), and no type material was mentioned in the original description, so the 'holotype' mentioned by Dugdale has no nomenclatural status.

Arctesthes siris (Hudson, 1908)

Figs 7, 8, 15, 24, 25, 31, 35 (map)

Lythria siris Hudson, 1908. Transactions and proceedings of the New Zealand Institute 40: 106.

Type material. Lectotype: male (designated by Dugdale (1988: 171)), '725a' [corresponding entry in G.V. Hudson collection register: 'Old Man Range at about 4000 ft. Feb '06 (J.H. Lewis)'] (MONZ) (not examined but photograph seen).

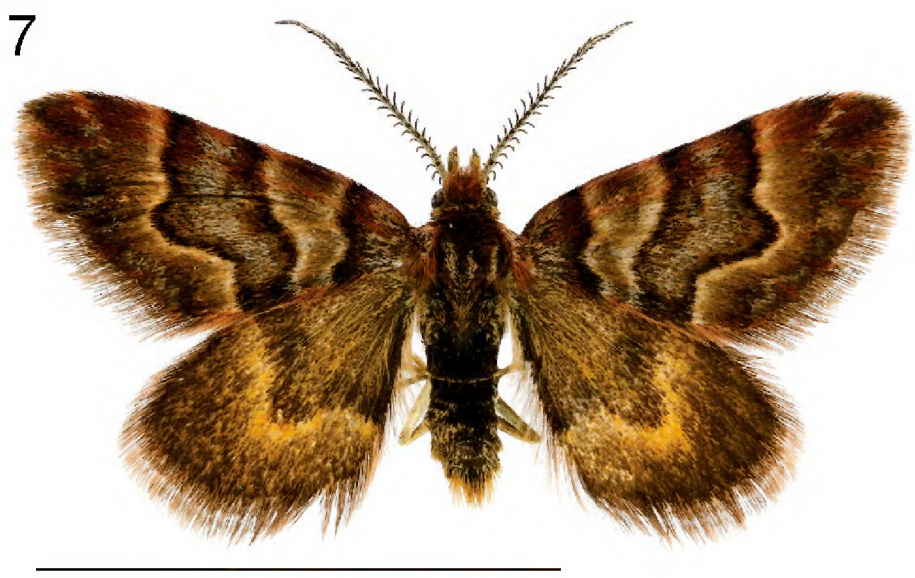
Diagnosis. *Arctesthes siris* is similar to *A. catapyrrha*, but on average smaller. It is easily distinguished by the proximal line of the forewing, which has a distinct concave curve below the middle of the wing; the proximal line in *A. catapyrrha* is convex (bowed away from the wing base). The hindwing pattern also differs strongly from that of *catapyrrha*: in *siris*, the orange coloration is only present as rather narrow V-shaped band beyond the basal blotch and as scattered scales elsewhere; in *catapyrrha*, orange is the dominant hindwing colour. The dark antemedian line that borders the hindwing basal blotch is much more strongly V-shaped than in *catapyrrha*.

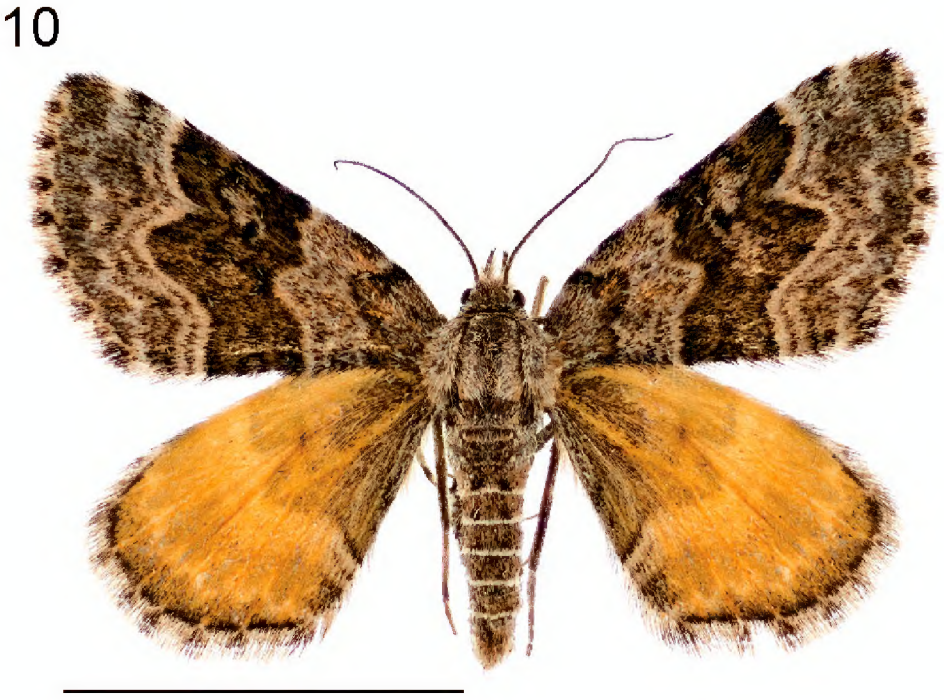
Redescription. *Adult male* (Figs 7, 15): Wingspan 14–16 mm. Male antennal pectinations shorter than in *A. catapyrrha*, up to ca 3–4× flagellum width. Labial palpi without hairlike scales projecting laterally, with moderately short, erect white to reddish brown hairlike scales ventrally. Head and thorax deep pinkish mixed with black and white; strip of pure white to deep pinkish scales along antero-ventral margin of eye. Forewing ground colour (areas between transverse markings) pale greyish brown, usually suffused with deep pinkish at least towards costa and dorsum and along veins distally; proximal line white, with slight concave curve below mid-wing; antemedian line white, gently sinuous; discal dot black, more or less equidistant between antemedian and postmedian lines or closer to antemedian; central fascia usually pallid, greyish in central band around discal dot, suffused pale brown exteriorly, dark lines or bands either side of this band contiguous with antemedian and postmedian lines; postmedian line white, strongly sinuous, with large V- to U-shaped evagination centrally, section between evagination and costa straight to very weakly convex; veins not lined blackish beyond discal cell; distal line grey, indistinct; fringe greyish, not chequered. Hindwing ground colour yellow-orange, but this colour only present as rather narrow V-shaped band beyond basal blotch and as scattered scales elsewhere; antemedian line strongly V-shaped and near wing centre; rest of wing suffused blackish without distinct lines; fringe brownish, paler distally. Forewing underside (Fig. 15) pale orange, with costa sometimes suffused deep pinkish; antemedian line absent; discal dot very small but distinct, black; postmedian line usually distinct, blackish, not double, with strong median evagination; no white spot on costa beyond postmedian line; subterminal fascia and subterminal line absent; terminal fascia represented at most by scattered suffusions of black scales. Hindwing underside pale orange, unmarked except for distinct black V-shaped antemedian line. Abdomen blackish, sprinkled white and orange, distal margin of each segment not usually distinctly paler; anal tuft mixed orange and white.

Male abdomen and genitalia (Figs 24, 25): S3-4 and 6 moderately elongate (rectangular), S5 more squarish, all sternites evenly sclerotised; T2-6 more or less evenly sclerotised but may have faintly desclerotised lines centrally and laterally. Uncus digitate, moderately robust basally, attenuate apically; labides rather short, broad, slightly curved, obliquely truncate apically; dorsal scobinate portion of manica with rather numerous blunt teeth; juxta triangular, with keel-like ventral lobe (juxta tending to flip over towards saccus in slide preparations); valva very short, rather narrow, with rounded-truncate apex; basal costal sclerite with straight costal edge, ending in short blunt process distinctly projecting beyond valval costa; sacculus process lobe-like to distinctly pointed, just reaching valval apex, not scobinate; saccus very short, blunt, somewhat recurved under genital capsule. Phallus (Fig. 25) with tongue-like apical process; vesica with 2 moderately long and a comb-like group of smaller cornuti (longer cornuti more basal in uneverted vesica).

Adult female (Fig. 8): Wingspan 16 mm. Similar to male, but antennae without pectinations; labial palpi more or less as in male; forewing and hindwing both tending to be slightly narrower than in male; forewing tending to be slightly paler with middle portion of central fascia more whitish grey (though in specimens with narrower central fascia, entire fascia may be pale brownish and discal dot absent).

Female genitalia (Fig. 31): Total length ca 1.9 mm. Ovipositor lobes subtriangular, apically blunt. S8 with weakly concave lamella postvaginalis not clearly distinguished from remaining S8 sclerite. Ostium round, narrow; antrum not differentiated from posterior portion of ductus bursae; ductus bursae not sclerotised, but thickly membranous, with weakly rugose posterior portion





Figures 7–11. *Arctesthes* spp., uppersides. **7)** *A. siris*, male, Zero Gully, Waikaia River CO; **8)** *A. siris*, female, Rock and Pillar Range CO; **9)** *A. titanica*, male paratype, White Burn, Von River OL; **10)** *A. titanica*, female paratype, White Burn, Von River OL; **11)** *A. titanica*, female, Von River north branch OL. Scale bars: 10 mm.

roughly equal in length and width to smooth anterior portion. Corpus bursae membranous, round.

Distribution. (Fig. 35). Confined to Central Otago: occurs between 1050–1140 m on the Lammermoor Range and 1200–1380 m on the Rock and Pillar Ranges of eastern CO, 1050–1150 m on South Rough Ridge further inland, 1150–1620 m on the Garvie Mountains, Old Man and Old Woman Ranges of nuclear CO, and 1700-1850 m on the Pisa Range further west. The species is not known from the adjacent Umbrella Mountains or The Remarkables, but may have been missed there.

CO.

Biology. Confined to mountains, where it lives in cushion wetlands and snowbanks. The adults fly by day low over the open vegetation and are found between early December and mid April; they can be locally common in these habitats. Larvae have not been described but have been observed to feed on various low-growing plants including *Plantago* and *Coprosma* (BHP, pers. obs.); unfortunately no photographs are available.

Remarks. This local Central Otago endemic was discovered by railwayman J.H. Lewis in February 1906,

high (over 1320 m) on the Old Man Range. BHP has recorded it 37 times since 1982 from seven discrete alpine areas (see Distribution above). In low alpine habitats of Central Otago, both *Arctesthes catapyrrha* and *A. siris* can sometimes be found flying together in cushion wetlands, such as at 1400 m on Symes Road on the Old Man Range [45°20.5'S, 169°13.7'E].

Arctesthes titanica Patrick, Patrick & Hoare, sp. nov.

http://zoobank.org/BC0ADE2C-9DCF-4F9F-9A81-C2CA8D148D9F

Figs 9–11, 16, 26, 27, 32, 35 (map)

Type material. Holotype: male (pinned), 'NZ OL 800m White Burn Sth Br Von R 4 Feb 2006 B M Lyford / NZAC slide Geo. 29 genitalia ♂' [South branch of Von River: 45°13'S, 168°21'E] (NZAC). Paratypes (1 male, 2 females): 1 male, same locality as holotype, 6 Mar 2004, B. & H. Patrick (NZAC) (Figs 9, 16); 1 female, same data as holotype but not dissected (Fig. 10) (NZAC); 1 female, same locality as holotype, 18 Feb 2004, S. Morris (genitalia on slide NZAC Geo. 32) (NZAC).

Other material examined. 3 males, 3 females, same locality as holotype, 6 Mar 2004, B. & H. Patrick; 4 females, same data as holotype but not dissected; 1 female, OL: North Branch of Von River, 18 Feb 2006, B.M. Lyford; 3 females, North Branch of Von River, 17–18 Feb 2007, B.H. Patrick (Fig. 11). (NZAC, BLNZ, BPNZ).

Diagnosis. This species can easily be distinguished from *A. catapyrrha* by its larger size (in spite of the slight overlap in wingspan measurements, this is always a much more robust, larger-winged moth) and the almost unmarked hindwing upperside. The strongly 3-lobed antemedian line on the hindwing underside is also diagnostic. Differences from *A. avatar* are given under that species, below.

Description. *Adult male* (Figs 9, 16): Wingspan 21–22 mm. Male antennal pectinations up to ca 4× flagellum width. Labial palpi without hairlike scales projecting laterally, with moderately long, dark grey hairlike scales ventrally. Head and thorax blackish with admixture of scattered white to silvery grey scales; strip of pure white scales along antero-ventral margin of eye. Forewing ground colour (areas between transverse markings) mid-grey, suffused with pale ochreous brown in basal blotch, central fascia and along veins distally (brown colour appears darker when not seen under magnification); proximal line pale grey mixed pale brown, with slight convex curve towards costa; antemedian line pale grey mixed pale brown, rather strongly V-shaped centrally; discal dot black, closer to antemedian than to postmedian line; central fascia usually mid- grey in central band around discal dot, black, strongly suffused pale brown exteriorly; postmedian line pale brown mixed pale grey, strongly sinuous, with large V- to U-shaped evagination centrally, section between evagination and costa weakly to strongly convex; veins lined blackish and speckled pale brown beyond discal cell; distal line pale grey, rather indistinct; fringe dark grey, weakly chequered blackish. Hindwing ground colour bright orange; basal blotch suffused blackish except in narrow strip along costa, the suffusion extending along anal margin of wing to anal angle; antemedian line represented only by variable short dark section adjacent to anal margin, but pallid, more or less W-shaped underside fascia beyond antemedian showing faintly through in normal light (not or barely visible in strong overhead light); postmedian line obsolete, except for slight smudge on anal margin; terminal line obsolete, but series of black dashes along termen very distinct; fringe blackish, distally with some brownish white scale-tips. Forewing underside (Fig. 16) pale orange; antemedian line absent or present only as dark smudge on costa; discal dot small, distinct, black; postmedian line distinct only in costal 1/3 of wing or less, blackish, double, with upper part of strong median evagination usually still represented where lines fade, sometimes suffused brownish between the two lines; outer line more or less distinctly edged white towards costa; subterminal fascia represented by series of brown elongate smudges between veins in costal 1/3 of wing; terminal fascia distinct, brown, narrowing and petering out towards tornus; a series of dark dashes along termen. Hindwing underside pale ochreous brown; basal blotch with scattered whitish scales, distal end of blotch a dark brown line, roughly following contours of antemedian line; antemedian line strongly 3-lobed, with third lobe cut off by anal margin of wing, invagination between first and second lobes incorporating distinct elongate discal spot; a very distinct white fascia beyond antemedian line, following its contours; weakly defined postmedian line beyond fascia, blurred distally into broad brown distal area, which is bisected by whitish scalloped subterminal line. Abdomen blackish, sprinkled pale brown, distal margin of each segment narrowly white; anal tuft blackish, with some scales tipped brownish white.

Male abdomen and genitalia (Figs 26, 27): S3-4 and 6 elongate (subrectangular), S5 more squarish, all sternites evenly sclerotised; T2-6 evenly sclerotised. Uncus digitate, narrow, attenuate and minutely hooked apically; labides very large, robust, strongly C-shaped, blunt apically; dorsal scobinate portion of manica with rather numerous sharp teeth; juxta flat, broad, tongue-shaped, with rounded blunt apex; valva moderately short, rather narrow, with rounded apex; basal costal sclerite with central process distinctly projecting beyond valval costa, (apex of sclerite bluntly rounded); sacculus process very large, C-shaped, projecting well beyond valval costa and apex reaching just beyond valval apex, dorsally and apically with dense fine spinules; saccus moderately short, very weakly 3-pointed, hardly recurved under genital capsule. Phallus without distinct tongue-like apical process; vesica scobinate, with two symmetrical cornutal patches, each containing numerous rather long, curved spine-like cornuti.

Adult female (Figs 10, 11): Wingspan 19–22 mm. Similar to male, but antennae without pectinations; labial palpi with ventral scales mostly brownish white; forewing ground colour distinctly paler than in male, with central fascia more strongly contrasting; forewing fringe distinctly chequered dark and pale.

Female genitalia (Fig. 32): Total length ca 2.4 mm. Ovipositor lobes subtriangular, apically moderately blunt. S8 with lamella postvaginalis broad, smooth and flat, lacking concavity. Ostium very broad; antrum a squat, broad sclerotised chamber weakly differentiated from posterior portion of ductus bursae; ductus bursae thickly membranous, not distinctly rugose, short and broad. Corpus bursae membranous, round.

Distribution. (Fig. 35). At present only known from two localities in the valley of the Von River, south of Lake Wakatipu, Otago Lakes.

OL.

Biology. The species is only known from intermontane wetlands. Both the north and south branches of the Von River harbour rather extensive valley floor wetlands that are a mixture of cushion and moss bogs at 800–820m, surrounded by short tussock or copper tussock (*Chionochloa rubra* subsp. *cuprea*) grasslands; individual wetlands are approximately 0.1–0.4 ha in extent. The cushion plant *Oreobolus pectinatus* is the dominant cushion species, but a wide range of grasses, herbs and sedges share this habitat. Adult moths have been found on four occasions between 4 February and 6 March, but as they were relatively numerous each time and in good condition, their flight period probably extends from late January to late March at least. Adult females laid yellow eggs on leaves which hatched 13 days later. Larvae were given a variety of exotic and native herbs to feed on of which *Plantago,* prostrate-growing *Coprosma*, *Ranunculus*, *Bellis* and *Trifolium* were eaten; however, rearing was unsuccessful. The first instar larvae are brown-grey in colour and quite active. Unfortunately, no photographs were taken of the larvae.

Etymology. Based on its large wingspan compared to *A. siris* and *A. catapyrrha*, the species is named (with an element of hyperbole) after the Titans of Greek mythology, primeval deities of enormous size and strength, and by extension after the legendary but ill-fated 'Titanic', in its time the largest passenger ship ever built and the subject of the popular James Cameron movie of 1997 (see also Etymology under *A. avatar* below). The name is a Latin adjective.

Remarks. Given the narrow distribution of this species and the fragility of its wetland habitat in an area still managed for extensive pastoralism, this species is threatened with extinction. Although the moth is relatively abundant where it occurs, the habitat is small and vulnerable to damage from farming practices such as over-sowing, grazing, stock trampling and vehicle damage. Additionally the areas are mostly unfenced, so recreational vehicles have access to these wetlands and could easily inflict damage as has occurred elsewhere in Otago and Southland.

Arctesthes avatar Patrick, Patrick & Hoare, sp. nov.

http://zoobank.org/FE52851D-72D6-46B8-B40B-8913C6290B43

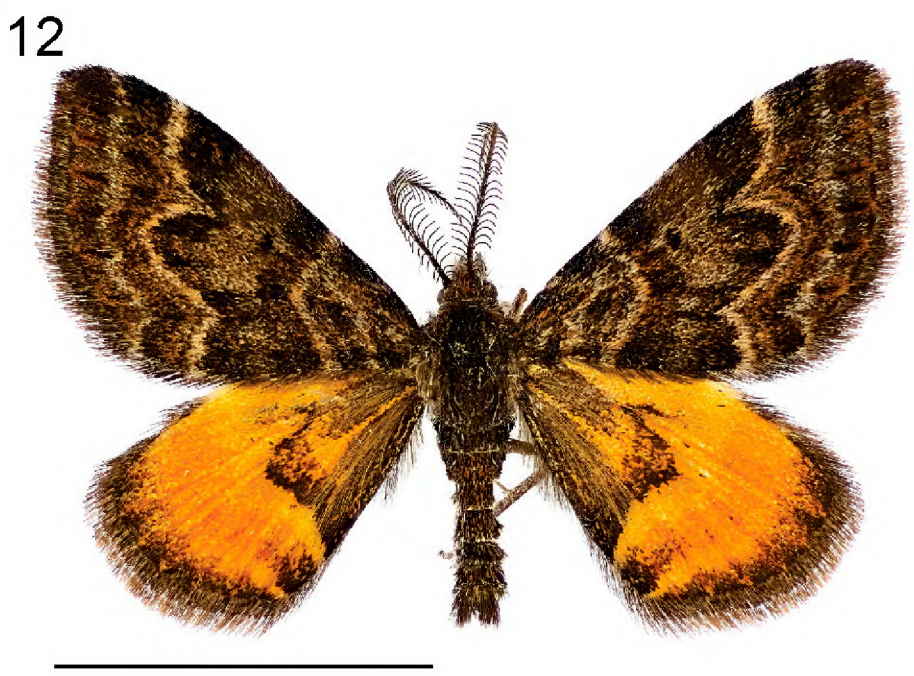
Figs 12, 13, 17, 19, 28, 29, 33, 35 (map)

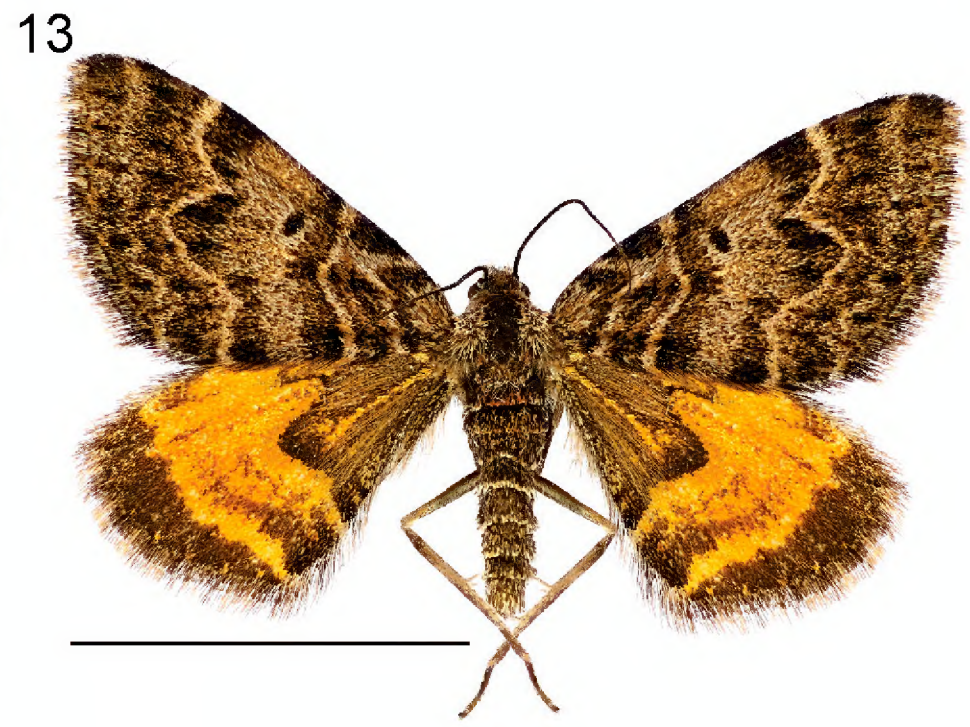
Type material. Holotype: male (pinned), 'NEW ZEALAND NN Denniston - Rochfort wetland area 855m 16–18 Feb 2015 Brian Patrick / NZAC slide Geo. 46 genitalia ♂' [41°46.3'S, 171°45.3'E] (NZAC). Paratypes (1 male, 1 female): 1 male, NN: Denniston Plateau 640–720 m, 16–18 Feb 2015, B.H. Patrick (Fig. 12); 1 female, NN: Mt Rochfort 1000m, 16 Feb 2015, B.H. Patrick (genitalia on slide NZAC Geo. 47) [41°46.7'S, 171°44.6'E] (both NZAC).

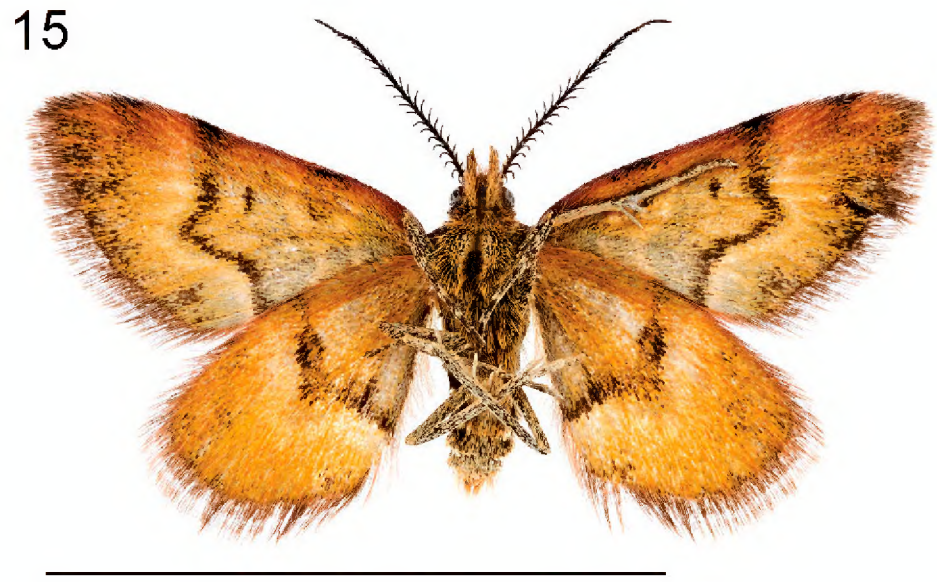
Other material examined. 1 male, same data as holotype; 2 males, 1 female (Fig. 13), NN: Denniston Plateau 640–720 m, 16–18 Feb 2015, B.H. Patrick; 1 male, Denniston Plateau wetland 650 m, 3 Mar 2012, B. & H. Patrick (Fig. 17). (BPNZ, NZAC).

Diagnosis. *Arctesthes avatar* is superficially similar to *A. titanica*. However, the species are almost certainly strongly allopatric and should be identifiable based on locality alone. The most conspicuous diagnostic characters are on the hindwing upperside and underside as follows: *A. avatar* has a very distinct wedge-shaped area of dark shading on the hindwing upperside from the base, enclosed by the strongly developed dorsal half of the antemedian line: in *A. titanica*, the antemedian line is reduced to a smudge on the anal margin only. *Arctesthes avatar* also has a strong dark terminal shade on the hindwing but lacks black dashes along the termen itself; in *A. titanica* the black dashes are present and distinct, but there is no terminal shading. The hindwing underside in *A. avatar* is predominantly very pale orange with only the antemedian line and terminal shading showing up conspicuously darker; in *A. titanica*, the hindwing underside is predominantly mid-brown with the area beyond the antemedian line and the subterminal line showing up conspicuously paler. In the male genitalia, the longer, narrower labides and much shorter sacculus process easily distinguish *A. avatar* from *A. titanica*.

Description. *Adult male* (Figs 12, 17): Wingspan 20–22 mm. Very similar to *A. titanica*, with the following differences. Forewing with antemedian and postmedian lines slightly better defined than in *titanica*; postmedian line with indentation above median evagination and level with discal spot tending to be more pronounced than in *titanica*. Hindwing with dark antemedian line reaching much further across wing than in *titanica* (about half way to costa), and then diverting basad to join small variably distinct discal dot; terminal line present as dark brown fascia, with weakly scalloped inner margin; black dashes along termen absent. Forewing underside (Fig. 17) with postmedian line more distinct than in *titanica* and almost complete, reaching to near dorsum. Hindwing underside with blackish suffusion from base; area basad of antemedian line largely pale orange (not brown) and without dark edging to basal blotch; white fascia beyond antemedian line rather indistinct; from here to terminal fascia



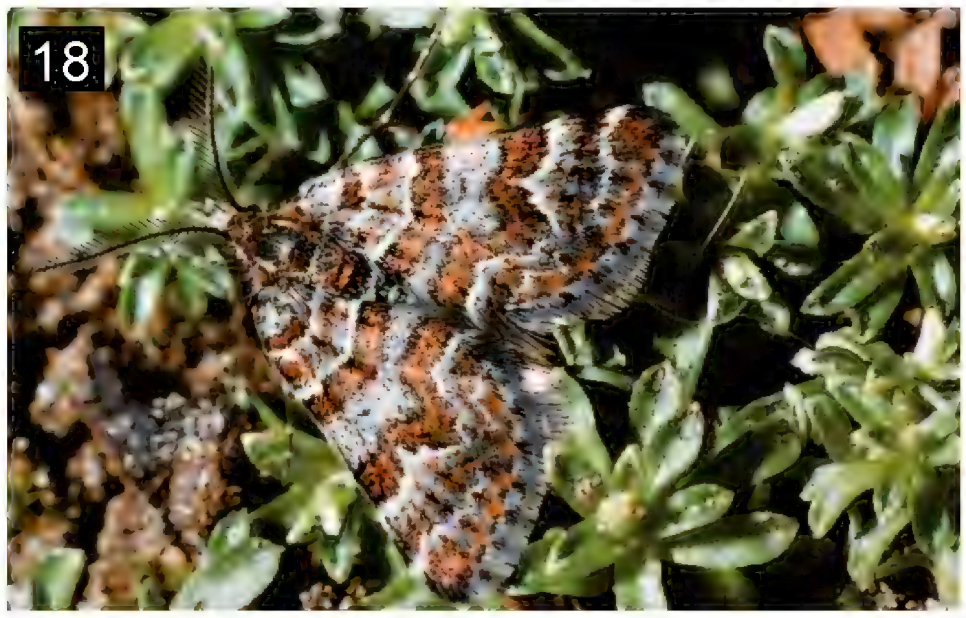




Figures 12–17. *Arctesthes* spp. **12)** *A. avatar*, male paratype upperside, Denniston Plateau NN; **13)** *A. avatar*, female upperside, Denniston Plateau NN; **14)** *A. catapyrrha*, male underside, Yaldhurst MC; **15)** *A. siris*, male underside, Zero Gully CO; **16)** *A. titanica*, male paratype underside, White Burn OL; **17)** *A. avatar*, male underside, Denniston Plateau NN. Scale bars: 10 mm.

pale brownish orange, with brownish smudge at anal angle representing postmedian line; subterminal line very faintly paler, not distinct as in *titanica* (where it stands out against brown background).

Male genitalia (Figs 28, 29): S3-4 elongate (subrectangular); S6 elongate (trapezoidal, tapered distally), S5 more squarish, all sternites evenly sclerotised; T2-6 evenly sclerotised. Uncus digitate, narrow and minutely hooked apically; labides large, robust (but distinctly narrower than in *A. titanica*), strongly C-shaped, blunt apically; dorsal scobinate portion of manica with rather few sharp teeth; juxta moderately narrow, flat, tongue-shaped, with rounded bifid apex; valva moderately short, rather narrow, with rounded apex; basal costal sclerite with sinuous central process, distinctly projecting beyond valval costa, (apex of sclerite bluntly rounded); sacculus process robust, short, truncate, with concave distal margin, barely projecting beyond valval costa and apex not reach-



Figures 18–20. *Arctesthes* spp., live adults and larva. **18)** *A. catapyrrha*, male; **19)** *A. avatar*, female; **20)** *A. catapyrrha*, larva.

ing valval apex, apically with dense fine spinules; saccus moderately short, V-shaped (narrower than in *A. titanica*), hardly recurved under genital capsule. Phallus without distinct tongue-like apical process; vesica scobinate, with two symmetrical cornutal patches, each containing numerous rather long, curved spine-like cornuti.

Adult female (Figs 13, 19): Wingspan 20 mm. Similar to male, but antennae without pectinations; forewing ground colour distinctly paler than in male, with central fascia more strongly contrasting; forewing fringe chequered dark and pale.

Female genitalia (Fig. 33): Total length ca 2.0 mm. As described above for *A. titanica*, but smaller; ovipositor lobes slightly blunter.

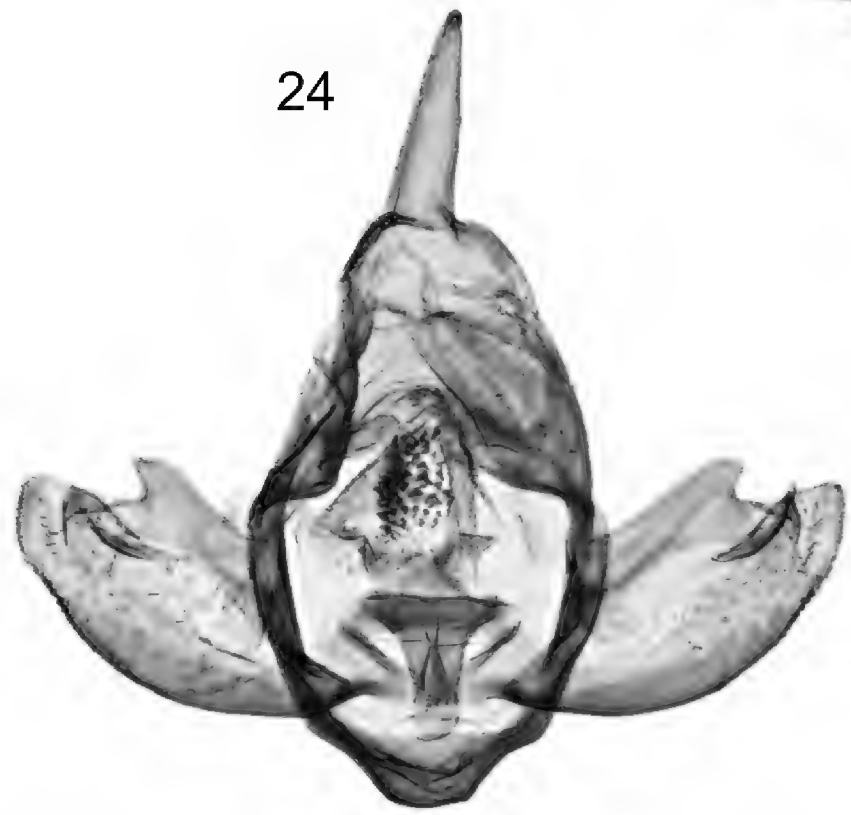
Distribution. (Fig. 35). Only known from the Denniston Plateau / Mt Rochfort area in the north-western South Island (Nelson district).

NN.

Biology. The species has been found at 640–1000 m a.s.l. in ephemeral wetlands of short sedges and herbs, including *Liparophyllum*, *Donatia*, *Ficinia*, *Oreobolus* and *Euphrasia* species. Specimens have been disturbed or taken flying by day from 6 February to 22 March. Females were observed to lay eggs in rows on the underside of leaves of *Liparophyllum gunnii* (Menyanthaceae) growing in the wettest areas. A larva reared from the egg in captivity was briefly described as brown dorsally, paler ventrally, and fed on dying leaves, stems and roots of *Liparophyllum*, but rearing was unsuccessful and it was not photographed. In a 2015 survey, BHP and Ian Millar found that *Liparophyllum* was the only dicot herb present at all sites where the moth was found, so, unlike other *Arctesthes* species, *A. avatar* may be monophagous on this plant.

Etymology. Forest & Bird, who organised the Denniston Plateau BioBlitz at which this species was found, ran a public competition to choose a name for this species. The 'avatar moth' was picked as the winning entry. The name refers to the James Cameron movie Avatar; like the indigenous people and fauna of that film, the moth is vulnerable to habitat change or destruction in its very limited area of occurrence. The original avatars of Hindu mythology were incarnations of deities, especially of Vishnu: one of these, Varaha the boar, is depicted in a Pahari miniature painting of ca 1740 with the black, white and orange coloration of *A. avatar* killing a demon and rescuing the Earth on his tusks (image available from Wikipedia: https://en.wikipedia.org/wiki/Chamba,_Himachal_Pradesh). The name is to be treated as a noun in apposition.

Remarks. The discovery of this species in 2012 was briefly discussed by Patrick and Patrick (2015). At first known only from a single specimen from one small site on the Denniston Plateau, it has since been discovered to be more widespread in wetlands from the Denniston Plateau to nearby Mt Rochfort, though still extremely localised and confined to potentially vulnerable wetland sites on the margins of a coal-mining area. The largest

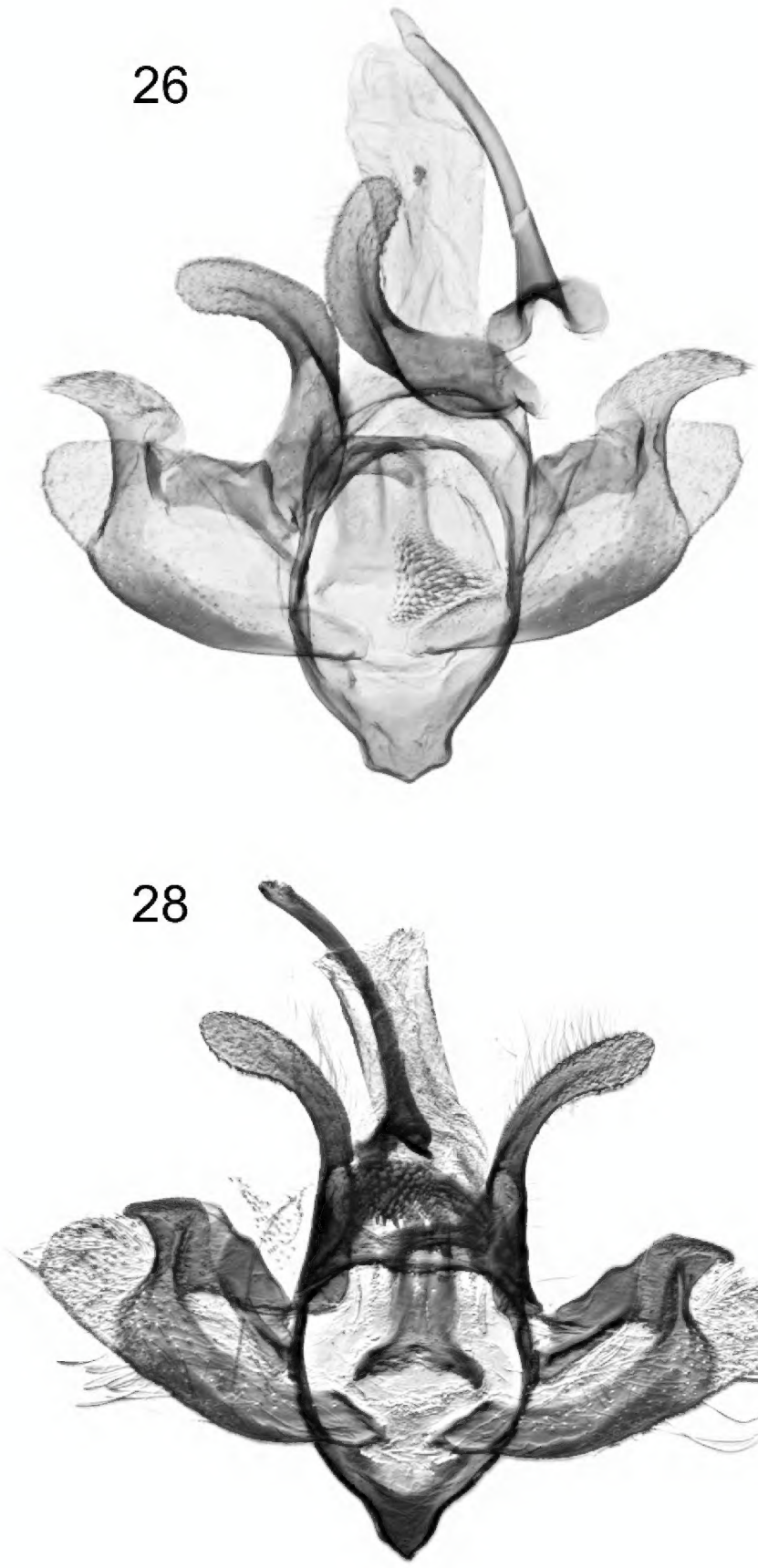


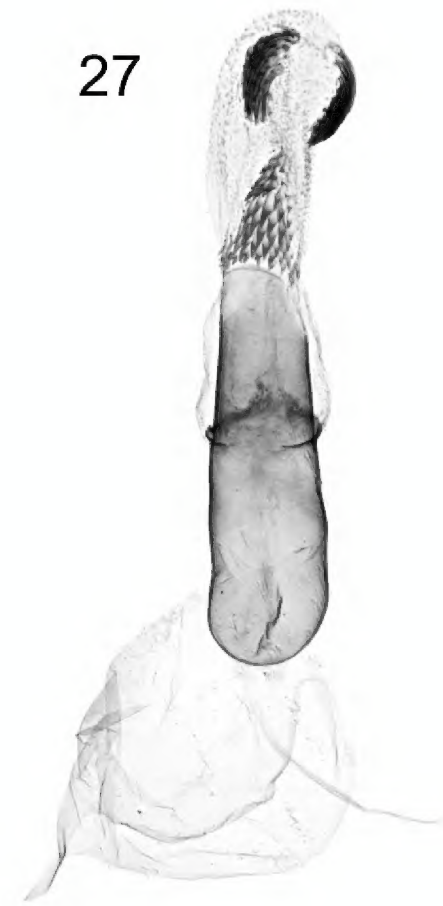
Figures 21–25. *Arctesthes* spp., male abdomen and genitalia (ventral view unless otherwise indicated). **21)** *A. catapyrrha*, male abdomen (unrolled); **22)** *A. catapyrrha*, genital capsule; **23)** *A. catapyrrha*, phallus; **24)** *A. siris*, genital capsule; **25)** *A. siris*, phallus.

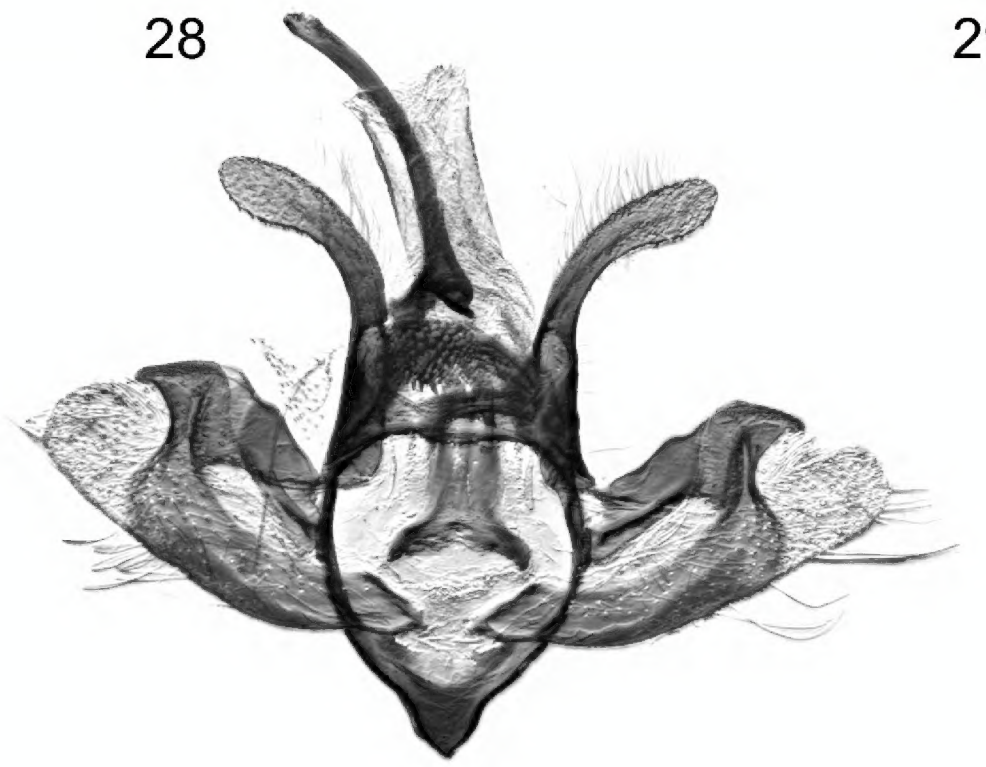
known population currently exists on the northern side of the old Denniston soccer field, where a wetland sward has developed. As with *A. titanica*, a high conservation status is appropriate for this moth.

Discussion

Hoare (2010a) listed 1703 named species and subspecies of New Zealand Lepidoptera: subsequent research on endemic genera (Patrick et al. 2010, Hoare 2010b, Hoare 2012, Hoare 2017) and on introduced species (Hoare and Hudson 2018) has brought that total to 1744. The Lepidoptera fauna is highly endemic at the species level (ca 85%): it can be characterised as moderately well collected, though many species are represented in collections by very sparse material, indicating that much remains to be discovered. The level of taxonomic understanding varies substantially between groups (cf. Dugdale 1988, Hoare 2010a), and knowledge of life histories is patchy and still lacking for a number of common species (cf. Hoare 2017). Many unnamed species are already recognised in collections and some of the more challenging groups (e.g. Psychidae, Gelechiidae, Oecophoridae) require substantial revision before the true composition of the fauna is understood. There are very few active collectors of Lepidoptera in the country at present. Nonetheless, earlier collectors covered much ground and did not neglect the



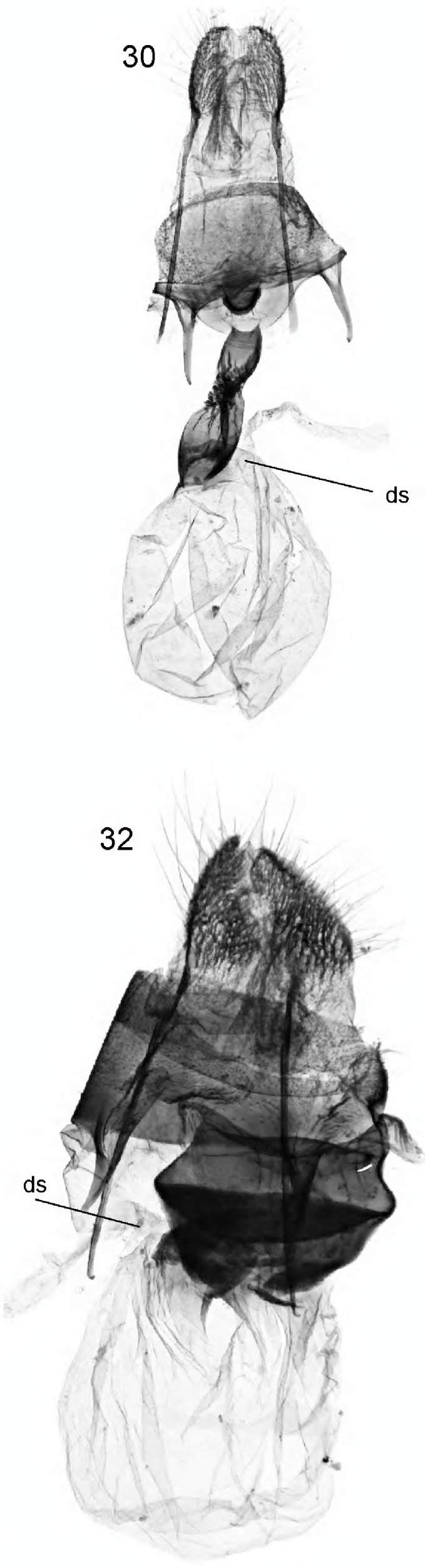


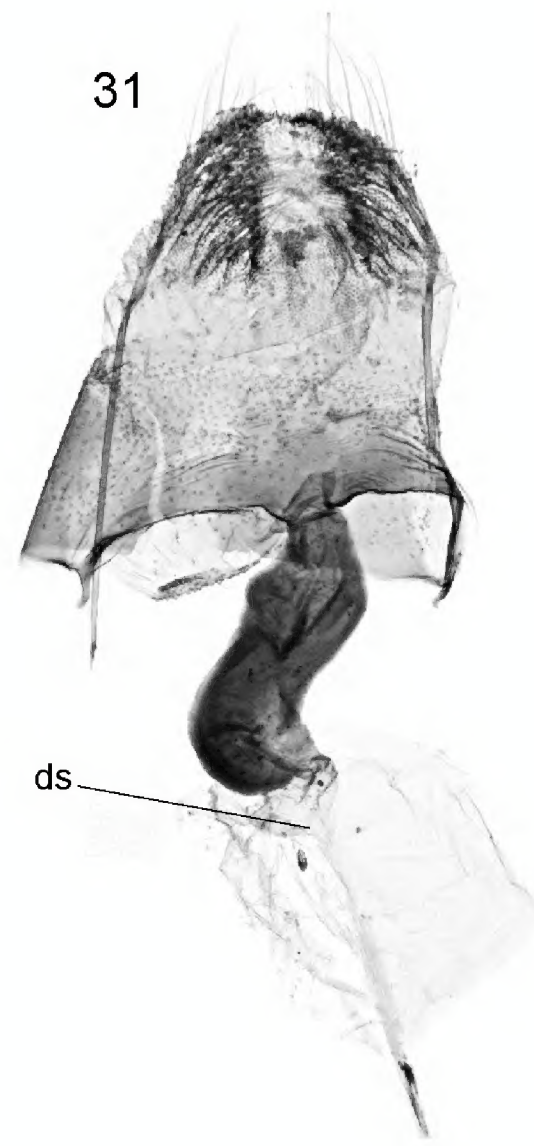


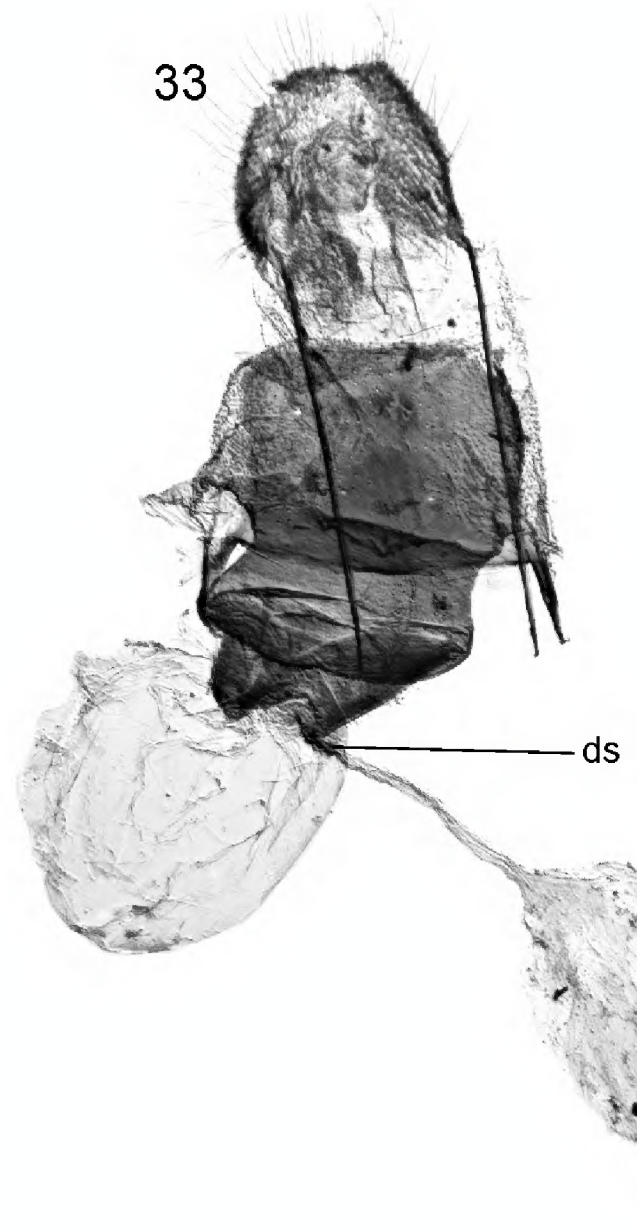
Figures 26–29. *Arctesthes* spp., male abdomen and genitalia (ventral view). **26)** *A. titanica* holotype, genital capsule; **27)** *A. titanica* holotype, phallus; **28)** *A. avatar* holotype, genital capsule; **29)** *A. avatar* holotype, phallus.

rich and extensive alpine zone of the South Island (see Dugdale (1988) for a historical summary). Further intensive surveys of the alpine zone from the 1960's to the present by John S. Dugdale, BHP and Brian M. Lyford (Queenstown) have greatly increased our knowledge. As a result, the discovery of previously overlooked endemic macro-moths is becoming a rare event. The two new species reported here are conspicuously patterned, day-flying insects; their late discovery must certainly be due to their extreme localisation in poorly sampled habitats. A very distinctive undescribed noctuid species has subsequently been found in the same habitat as *Arctesthes titanica* by B.M. Lyford, indicating the importance of the Von Valley as an area of narrow-range endemism in Lepidoptera.

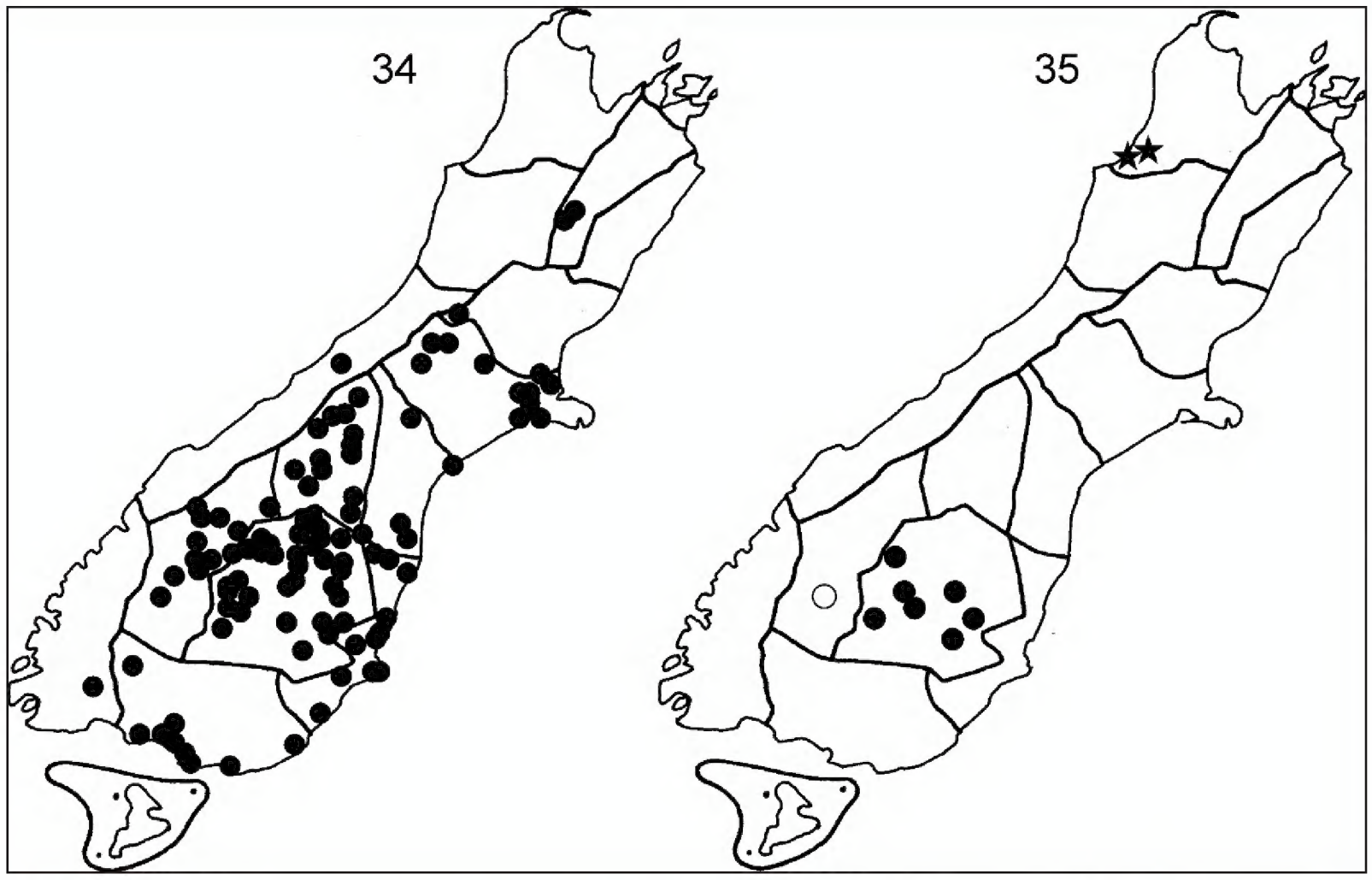
We have described the two new *Arctesthes* species here to promote their future monitoring and conservation, and to highlight the need for continued Lepidoptera survey work in the New Zealand alpine zone. Quantitative studies as well as work on life histories and ecology are particularly needed. Already one formerly common endemic geometrid species, *Xanthorhoe bulbulata* (Guenée, 1868), has declined drastically and is feared possibly extinct (Patrick 2000, Hoare et al. 2017): its life history and host-plant have never been discovered. Without further intensive study of the fauna of modified and threatened New Zealand environments, we will be unable to prevent other species slipping away.







Figures 30–33. *Arctesthes* spp., female genitalia (ventral view). **30)** *A. catapyrrha*; **31)** *A. siris*; **32)** *A. titanica* paratype; **33)** *A. avatar* paratype; (ds = ductus seminalis inception).



Figures 34, 35. *Arctesthes* spp., known distribution, New Zealand: South Island. 34) *A. catapyrrha*; 35) *A. siris* (black circles); *A. titanica* (open circle); *A. avatar* (stars).

Acknowledgements

We are grateful to Eric Edwards, Department of Conservation, Invercargill, for showing BHP the collections of insects from the Von Valley that contained *Arctesthes titanica* in a timely manner, enabling an expedition to the site while the adults were still flying. We thank Forest and Bird for organising the BioBlitz on the Denniston Plateau in March 2012 that led to a further new species of *Arctesthes* being discovered. Additionally we acknowledge the skill and patience of Birgit Rhode of Manaaki Whenua—Landcare Research, Auckland, in taking and editing the colour photographs of set adult moths and structural features and putting together the plates. We sincerely thank Axel Hausmann and Pasi Sihvonen for their helpful reviews of this manuscript. This work was funded in part by Core funding for Crown Research Institutes from the Ministry of Business, Innovation and Employment's Science and Innovation group.

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